

In situ X-ray observation of the stability of magnesite throughout the Earth's lower mantle

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Carbonates, such as CaCO_3 calcite and aragonite, MgCO_3 magnesite, and $\text{CaMg}(\text{CO}_3)_2$ dolomite are important constituents of marine sediments and play a fundamental role in the long-term recycling of carbon into the Earth's deep interior via subduction of oceanic plates. It has been demonstrated that these subducted carbonates react with surrounding silicates and/or decompose to CO_2 -bearing assemblages at certain depths in the upper mantle, and therefore MgCO_3 magnesite is believed to be the major carbonate in the deeper part of the upper mantle near 660 km (e.g. Biellmann et al., 1993). Study of the stability of magnesite under the pressure and temperature corresponding to those of the whole mantle condition is thus crucial in modelling the carbon circulation in the entire Earth system. However, such experiments have been limited to the upper mantle conditions with few exceptions (e.g. Katsura et al., 1991). Moreover, most of these studies adopted quench method, and no in situ X-ray diffraction measurements have been made under simultaneous high pressure and high temperature conditions of the lower mantle.

We firstly made in situ X-ray diffraction study of the stability of magnesite at P-T conditions approaching the mantle-core boundary using a laser heated diamond anvil cell (LHDAC) at BL10XU, details of which have been reported in Isshiki et al. (2004). We found magnesite persists to pressures up to about 100 GPa, at temperatures to 3000 K, without dissociation into the CO_2 -bearing assemblage. However, we noted that magnesite transform to a new phase (magnesite II) at pressures above 115 GPa, at 2200K (equivalent to a depth of ~2600 km in the lower mantle). Although we were unable to refine the crystal structure of magnesite II, the observed X-ray diffraction peaks were reasonably indexed on the basis of an orthorhombic symmetry, yielding a density of 5.20 g/cm³ at ~120 GPa at the room temperature.

Magnesite II was quenched to the ambient temperature under compression, but its diffraction peaks were lost on releasing pressure below ~100 GPa. TEM observations were made on the recovered sample after preparing a thin film by Focused Ion Beam (FIB) technique. We actually found that the central part of the LHDAC sample was amorphized, which was likely to be converted from magnesite II on release of pressure, while the colder part of the sample near the pressure medium was magnesite (see Isshiki et al. in this abstract for further details).

The present results demonstrated that the dissociation of magnesite into MgO and CO_2 is unlikely to occur throughout most part of the lower mantle. Subducted oceanic plates are significantly colder than the surrounding mantle into the uppermost part of the lower mantle, and accordingly magnesite should survive and be transported down to the upper mantle-lower mantle boundary at ~660 km depth without dissociation into a CO_2 -bearing assemblage. Moreover, parts of the stagnant plates at these depths may ultimately sink into the lower mantle after they are accumulated to a critical size to form a megalith structure. Thus magnesite is likely to be transported further down into the lower mantle, there to transform into magnesite II at 110 - 120 GPa, which may be the major host for oxidized carbon in the D" layer.